PROGRESS REPORT OF COMMITTEE ON STANDARD METHODS FOR THE EXAMINATION OF AIR.

Read before the Laboratory Section, American Public Health Association, Washington, D. C., September, 1912.

The Committee on Standard Methods for the Examination of Air made its first report three years ago recommending certain standard procedures for the determination of temperature, humidity, light, carbon dioxide and bacteria (published in the *American Journal of Public Hygiene* for May, 1910). At that time, very little work had been done from a practical sanitary standpoint on the physical and bacteriological aspects of our work, and the report was necessarily of a somewhat tentative nature. At the Havana meeting of the American Public Health Association, the committee was continued with the following membership: Dr. T. R. Crowder, Prof. M. J. Rosenau, Dr. G. A. Soper, Mr. J. Bosley Thomas, Prof. John Weinzirl, and Prof. C.-E. A. Winslow, chairman. The committee felt that a revision of certain sections of its earlier report was clearly desirable. In the time at its disposal, it has not, however, been able to arrive at final conclusions. There are still but few workers engaged in the practical study of atmospheric conditions from the sanitary standpoint, and the chemistry and bacteriology of air are far less developed than the chemistry and bacteriology of water and milk.

Before a definite and final report worthy of the confidence which the name of the committee and the association imply, can be made, much more research will be required. Methods will have to be tested, compared and, in some cases, actually devised. Two or three years of time should be given to the committee for this work and the committee respectfully asks for this time. By the end of such a time the committee believes it will be able to announce a set of definite procedures which can confidently be recommended as worthy of adoption as standard.

Meanwhile, however, the committee submits the following interim report showing the present progress and tendency of its work. It is hoped that such suggestions may be of some assistance to the workers in this field during the coming year and that they may bring from such workers the suggestions and advice which the committee needs for the completion of its work. The present report is, however, in no sense to be taken as a final and definite one.

Determinations to be Made in the Examination of Air.

The original conclusion of the committee, that the determinations of temperature, humidity, dust and intensity of light provide the most

important data to be secured in a sanitary study of atmospheric conditions, while tests for carbon dioxide and bacteria are useful for special purposes, seems to have been amply confirmed by subsequent experience. The committee believes, however, that the time has come for the inclusion of chemical tests for certain specific poisonous substances, like carbon monoxide, wood alcohol, arsenic and the like, which are discharged into the air by the combustion of fuels and in the course of industrial processes and which have an important bearing on the public health.

Temperature and Humidity.

The standard methods recommended in 1909 for the measurement of temperature and humidity—the recording thermometer and the U. S. Weather Bureau Sling Psychrometer—appear on the whole to have proved quite satisfactory, and the committee believes that no essential change in either is desirable. The swinging joint of the sling psychrometers on the market gives a little trouble in practice and some observers have complained of serious breakage of the instruments in the hands of their inspectors. General experience, however, seems to indicate that with a little training inspectors learn to use the sling psychrometer without serious difficulties.

Dust.

The committee in its 1909 report recommended two procedures for determination of the number of dust particles present in the air,—the use of the koniscope and the sugar filtration and microscopic counting method.

The committee hopes to study the koniscope further during the coming year, but is at present inclined to the view that this instrument is much less suitable for general sanitary purposes than is the filtration method. The standardization of the koniscope offers serious difficulties since it depends upon the recognition by the eye of the depth of color produced by fog in a vacuum tube. More serious, however, is the fact that the koniscope reveals all the minute ultra-microscopic particles in the atmosphere and thus masks the differences in the number of fairly large particles (such as industrial dusts) in which the sanitarian is interested. For example, in a recent study of the air of New York streets and schools by the filtration method, it was found that the number of dust particles generally varied between 400,000 and 1,000,000 per cubic foot. Macfadyen and Lunt (*Transactions of the British Institute of Preventive Medicine*, I, 142), on the other hand, found about 9,000,000,000 dust particles per cubic foot in ordinary indoor air by the use of the dust counter, which works on the same general principle as the koniscope but is the more exact instrument. The dust counter determines exactly, and the koniscope

determines approximately the number of particles down to a very high degree of fineness of the particles. What is needed for sanitary purposes is a reasonably accurate determination of the comparatively few, but rather large, particles which lacerate the epithelial tissues and favor the development of disease.

The filtration method gives this latter information, accurately measuring the number of particles large enough to be seen under a $\frac{2}{3}$ inch objective. As tested out by members of the committee it has proved on the whole satisfactory. The worst feature of it is the slowness of the sampling process due to the necessity of forcing a large amount of air through the small sugar filter. This difficulty has been mitigated to a considerable extent by the following changes: Instead of using a small glass tube, as recommended in the 1909 report, the committee in its recent studies has used a chemical adapter (a conical piece of glassware seven inches long having openings of $\frac{5}{8}$ inches at the smaller end and $1\frac{1}{2}$ inches at the larger end). The small end is closed with a perforated rubber stopper over which is placed a piece of bolting cloth to support the filtering layer made up of about 2.5 grams of granulated sugar, forming a layer 1 cm. deep. This modification of the older sugar filter was devised in the course of an investigation of the air of New York schools carried out by Prof. Charles Baskerville and the chairman of this committee. Five cubic feet of air can be drawn through this filter in eighteen minutes. The sugar is dissolved and the contained dust suspended in 10 cc. of distilled water and 1 cc. of the suspension is placed in a Sedgwick-Rafter counting cell and counted under the $\frac{2}{3}$-inch objective.

Another method of determining dust particles which is still quicker and simpler, has been used by Dr. C. T. Graham-Rogers of the New York State Department of Labor and was described by him in a paper read before the International Congress of Applied Chemistry in New York. He uses a glass cylinder 8 cm. in diameter and 20 cm. long with the top and bottom closed by perforated round glass stoppers. About midway in the cylinder is suspended a Petri dish of such a size as almost, but not quite, to fill the cylinder. The Petri dish is ruled in squares and smeared with glycerine. The air to be examined is drawn downward through the cylinder, so that it strikes the surface of the glycerinated plate and deposits its dust particles before finding its way around its edges, and the particles so deposited are counted directly under the microscope by the aid of the rulings on the plate. The committee hopes to make a study of this procedure in comparison with the sugar filter method during the coming year.

For collecting samples for dust determination, the following apparatus was found serviceable in the study of New York schoolroom air, to which reference has been made above. The air was drawn through the filter by means of a double suction pump (Eimer and Amend No. 750) which is

like a bicycle pump except that it has a double acting valve. To compensate for the puff of back pressure at the end of a stroke, a tight tin box was placed between the pump and the filter as an equalizing chamber. On the other (or pressure) side of the pump was connected a standard Brazilian type gas meter for measuring the amount of air filtered.

Illumination.

The committee believes that careful study should be given to the Sharpe-Millar photometer and other recognized methods of measuring the intensity of illumination in the hope of finding a procedure which will be superior to the use of sensitized paper recommended in 1909 and which will still involve the use of neither very costly nor cumbrous apparatus.

Carbon Dioxide.

In the 1909 report the Petterson-Sondén and Petterson-Palmquist methods were recommended for accurate work, but on account of the cost and complexity of the apparatus the Cohen and Appleyard time method was recommended for practical sanitary work. Evidence has accumulated, however, which indicates the unreliability of the latter procedure; and meanwhile the apparatus required for the Petterson method has been simplified and cheapened. There are at least two forms now on the market which are reasonably satisfactory and one or the other of them may probably be adopted as standard after further study. The general principle of all these methods is the measurement of a given volume of air and the absorption of the contained carbon dioxide in potassium hydroxide. The remainder of the air is measured, thus giving the volume of carbon dioxide by difference. The air is measured accurately by means of readings on a very finely graduated capillary tube, and all measurements are, of course, made at the same temperature and pressure. The principle is simple but dependable results are obtained only after considerable practice and a thorough mastery of the technique of operation.

A modified form of the Petterson-Palmquist apparatus has recently been prepared in this country by Eimer and Amend of New York, which can be obtained for about fifty-five dollars. It has the advantage of a considerably reduced bulk, and it is portable when fitted with an outer casing. Samples of air can be analyzed with this apparatus in about five minutes by a careful and skillful operator. It has been tested extensively by one member of the committee (Doctor Crowder) and by Doctor Graham-Rogers, and has been found eminently satisfactory.

The other apparatus which seems most promising is the portable apparatus designed by Haldane for the determination of CO_2 O_2 and CH_4 described in the *Journal of Hygiene*, for 1906, p. 74. This apparatus can

be obtained from F. P. Rittenhaus & Co., 53A Huntly Street, Tottenham Court Road, London, W. C., at a price of $20 and requires about three months to import. Eimer and Amend can make the same apparatus for $35 in about two weeks. Rittenhaus, according to Haldane, also makes a much smaller apparatus for CO_2 only, for $15 (described in Notter and Firth's *Hygiene*). The larger Haldane apparatus has been carefully tested by one member of the committee (Doctor Rosenau) and found to be simple and accurate. It should be noted that the Haldane apparatus is made up in two forms, one for use in mines and one for ordinary use. The mine apparatus is not sensitive enough for use in ordinary ventilation studies.

For the Petterson-Palmquist or the Haldane methods of analysis the samples are collected in two-ounce, glass stoppered bottles of clear glass if the analysis is not made with the portable apparatus on the spot. These bottles hold about 70 cc., which is enough air to make two analyses, in case it should be necessary—and it is always advisable—to repeat determinations. The stopper of each bottle is greased with petrolatum, or with a mixture of petrolatum and soft paraffine which will spread readily under pressure; and after the sample is taken, the stopper should be turned round and pressed down until no air channels are visible in the petrolatum. The stopper is held in position by a stout elastic band passed over it, and a gummed label is placed on the bottle.

The bottles *must* be dry, and they should also be clean. They should be rinsed with clean (preferably distilled) water and completely dried. If a bottle is wet and dirty an appreciable amount of CO_2 may be produced or some may disappear by bacterial action. If, on the other hand, the bottle is wet and clean, carbonic acid gradually disappears, as it is absorbed by alkali dissolved out of the glass by the water. In *dry* bottles, even though dusty inside, no sensible alteration takes place within a fortnight or more.

The sample may be collected as follows: One end of a piece of rubber tubing, two or three feet long and one-eighth or one quarter of an inch in diameter, is introduced to the bottom of the bottle, the other end being held in the mouth. A deep breath is then sucked in through the tube, so that the bottle is completely washed out by the surrounding air. The tube is removed while the air is being still sucked in, so as to avoid any risk of the breath passing backward into the bottle. The stopper is then inserted, turned around, and secured as already described, and particulars written on the label. Care must, of course, be taken that the sample be not contaminated in any way by the presence of persons or lamps. If it is desired to take samples at some distance from the operator, the plan may be varied by fitting the breathing tubes by a glass connection to one of the holes in a double bored rubber stopper which will just fit

the bottle. Into the other hole, and ending just below the stopper, should be fitted another tube through which the air enters. If this second tube has great length, several breaths should be sucked through in succession, in order to entirely displace the air originally contained in the tube.

Samples may be first collected in large rubber bulbs, such as are used with the Paquelin cautery or the sphygmomometer, and then transferred by passing the outlet tube to the bottom of the bottle. If the bulb holds 800 or 1000 cc. there need be no fear about completely displacing the original air of the bottle. This method has the advantage that one sample of the air may be collected from many points in a room, and will in consequence be an average sample.

The water siphon method, the steam vacuum method, and others discussed in our earlier report have the disadvantage of a wet container. This may not matter if the analysis is to follow immediately upon the collection, but it is not recommended where any considerable interval is to elapse.

When larger containers than can be manipulated readily by breathing are to be used, some sort of a small hand bellows or suction pump is recommended for displacing the air in the container.

Care must be taken in transferring the air sample to the apparatus, that there is no contamination. A method which has proven very satisfactory and is free from sensible error in the use of the Petterson-Palmquist method of analysis is as follows:

Remove the stopper of the bottle containing the sample to be analyzed under a saturated solution of pure sodium chloride. A little air will escape or a little of the solution will enter and by this the pressure in the bottle will be equalized to that without. Lift the bottle until the fluid in the neck is level with the surface of that in the basin. Slip a finger over the mouth of the bottle and transfer to any convenient stand near the mouth of the pipette. Slip the finger off sideways and immediately insert a double-bored rubber stopper which will fit snugly. This stopper should be previously made ready for use by inserting two small glass tubes through its bores, one of which will reach well toward the bottom of the bottle, and one of which ends just below the stopper. To the longer glass tube is attached a rubber tube which acts as a siphon leading from a large bottle of saturated sodium chloride solution placed at a higher level. This siphon is kept always full of the solution which is held back by a pinch-cock. To the shorter glass tube is attached a very narrow rubber tube (a small catheter with a conical tip answers best) which will reach to the mouth of the apparatus. As soon as the stopper is in place, press the pinch-cock and thus allow the salt solution to run into the bottle. This causes some of the sample of air to flow out through the small tube. When all of the air originally contained in the tube has been displaced, the free

end is attached to the pipette and the air let in, being forced out of the bottle by the flowing salt solution.

After equalizing the pressure in the bottle by the process described there is no sensible interchange of gases during the moment of removing the finger and inserting the rubber stopper.

Detection of Poisonous Gases.

It would be desirable in the future to formulate standard methods for the estimation of a number of gases and noxious vapors which may be found in the air of factories and other industrial establishments, and for the carbon and tar represented in soot, and the sulphuric acid which exerts important effects in city air. The committee has been unable to go into this aspect of the work as yet, but desires to call attention to two methods used by Doctor Graham-Rogers in the work of the New York State Department of Labor as deserving of special study.

In one method used by Dr. Graham-Rogers for the determination of carbon monoxide air is drawn through U tubes containing caustic potash, sulphuric acid and anhydrous iodic acid along with three to four times the amount of large pieces of pumice stone. Heating in an oil bath at 150 degrees converts the carbon monoxide to carbon dioxide and liberates iodine which is titrated with $\frac{1}{1000}$ normal sodium thiosulphate. When 3-4 liters of air are used, one part in 40,000 parts of air can be detected.

For the determination of wood alcohol, Doctor Graham-Rogers aspirates 250–500 liters of air through wash bottles containing distilled water. A fractional part is allowed to stand half an hour with 4–5 grams of potassium dichromate and 3–4 cc. of concentrated sulphuric acid. The formic acid produced may be estimated by acidimetry or saturated with barium sulphate and precipitated as barium formate.

Bacterial Count.

The most important new method suggested for enumerating the bacteria in air since our 1909 report is that described by Rettger in the *Journal of Medical Research* for June, 1910, in which air is bubbled through water by the use of a glass bulb with very small perforations. This procedure seemed promising and has been carefully studied and compared with the sand filter method by members of the committee (Professor Weinzirl and Mr. Thomas).

In setting up the apparatus each used the sand filter as described in the standard methods, but it soon appeared that some modification was necessary. It was evident that the large opening of the sand filter tube might receive, by the direct settling of dust, a greater number of bacteria than the smaller opening of the aëroscope. Mr. Thomas met the diffi-

culty by protecting the opening with an aluminum shield, while Mr. Weinzirl reduced the size of the opening by inserting a stopper fitted with a glass tube of the same diameter as the aëroscope tube and bent in a similar manner. The aëroscope also differed slightly; Mr. Thomas omitted the bulb, but closed the end of the tube, filed notches nearly through the walls, and made the holes in these notches with a very sharply pointed file, while Mr. Weinzirl duplicated Rettger's apparatus. It is believed that this difference is not essential.

In the trials the filter openings were as near together as possible, the distance being usually an inch or less. The bacteria were supplied by beating cloths which had been rubbed over the laboratory floors and steps. Eight-liter, graduated bottles were used as aspirators, the rates of filtration being equalized by means of screw clamps applied to the siphons. It was difficult to maintain exactly uniform rates of filtration, but care was taken to obtain as nearly uniform rates as possible before the air was charged with dust.

Under the conditions as outlined above, the results obtained agreed fairly well, although Weinzirl secured almost an equal number of excesses for both methods, while Thomas secured excesses only by the sand filter method. As the excesses (particularly those obtained by Weinzirl) are not large, and as the second tubes show only small numbers of bacteria, the two methods compare favorably so far as accuracy is concerned.

The question then resolves itself largely into one of the comparative convenience of the two methods. While it is somewhat easier to make plates from the water filter, we find the sand filters in every way easier to operate. The aëroscopes are more difficult to make, or more expensive if purchased; they are more easily broken; and when being handled they frequently get out of order. Again, sand filters, if protected, may be used some time after being sterilized, while the aëroscopes tend to lose water by evaporation during sterilization and storage, thus vitiating the accuracy of the work. In actual sanitary work, when many samples are to be taken, and at a distance from the laboratory, we believe that the aëroscopes would give more trouble than the sand filters. Although no work has been done to confirm the belief, it seems not improbable that under certain conditions the absorption of sulphur dioxide or other gases in the five cc. from ten to twenty liters of air might have a restraining action upon the growth of some of the organisms absorbed.

The corks used in the sand filters are soon ruined by the heat, and unless great care be exercised, they are liable to leak. It was found that rubber stoppers may be substituted if the tubes are sterilized in the autoclave. We would recommend their use.

It was obvious, as mentioned above, that the large opening of the tubes permits gross particles to enter by force of gravity. We would, there-

fore, recommend that the mouth be closed by an additional stopper fitted with a very short glass tube bent at an angle of about 45 degrees.

In the comparative tests the absorption efficiency of the tubes was probably more severely taxed than it would be in actual practice. In our judgment, the use of the second tube affords but little additional advantage, while it does render the method cumbersome, and the slight additional accuracy does not justify the extra labor involved. We would, therefore, recommend the use of single tubes only. Otherwise the method recommended in 1909 seems on the whole satisfactory.

Respectfully submitted,

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John Weinzirl.
C.-E. A. Winslow, *Chairman.*

Doctor Soper's Reasons for Declining to Sign the Report of the Committee on Standard Methods of Air Analysis.

1. I object both to the form and substance of the majority report.

2. I have not been given a chance either to test the new methods referred to or give them the careful thought which they should receive from each member of the committee before being reported upon.

3. In many respects the majority report is open to severe criticism such, for example, as was properly made against the first report of this committee.

4. The theory of the report is wrong. The committee should not report methods which merely seem worthy of study, but should do the studying required and announce the results in plain and concise language.

5. In the absence of the sound and sufficient knowledge which should lie at the bottom of the report, the committee should be brief and conservative.

George A. Soper.